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Competing options for decarbonising residential heating in the UK

Graeme Hawker, University of Strathclyde

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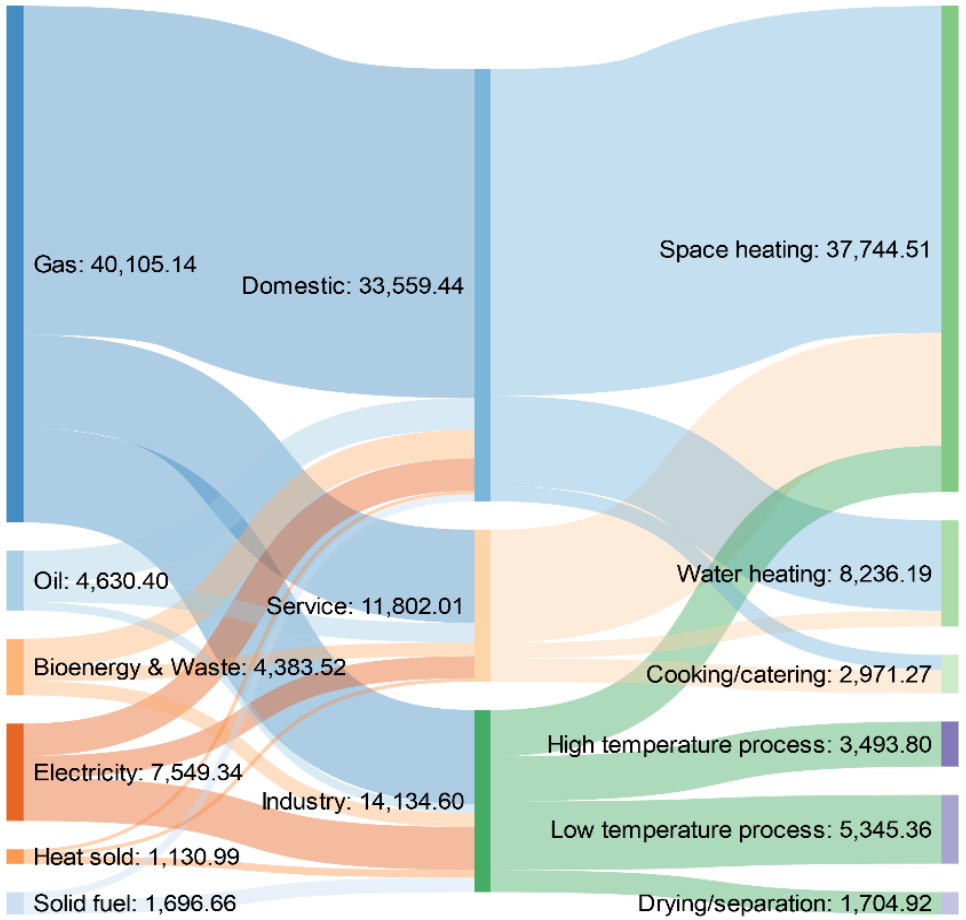
Background

28 million households in the UK

Residential heat generation represents 23% of final UK energy demand, 76% of which is met using natural gas

Electricity is the second most important energy carrier but supplied just 13% of UK heat in 2017, mostly through immersion tanks and Economy 7 storage heating

District heating represents just 2% of total heat supply (0.8% of domestic heat) but has been growing significantly: UK network numbers total 17,000 as of January 2018 and supplies close to 500,000 customers, up from 2,000 and 211,000 respectively in 2013 (ADE, 2018)



BEIS, Energy Consumption in the UK 2018

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Recent Policy

- Spring statement: “to help ensure consumer energy bills are low and homes are better for the environment, the government will introduce a Future Homes Standard by 2025, so that new build homes are future-proofed with low carbon heating and world-leading levels of energy efficiency”

- CCC: “From 2025 at the latest, no new homes should be connected to the gas grid. They should instead be heated through low carbon sources, have ultra-high levels of energy efficiency alongside appropriate ventilation and, where possible, be timber-framed.”
  - “[existing] …homes should use low-carbon sources of heating such as heat pumps and heat networks.”

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The UK Context

- Spatially heterogeneous population
  - 33% urban, 39% suburban, 28% rural by household
- Large volume of ageing housing stock
  - Limited progress in improving efficiency
- Ageing T&D network
  - Particularly constrained at local scales
- Plentiful renewable resources
  - Large volumes of curtailed energy
- High natural gas penetration
  - Second only to Netherlands in EU

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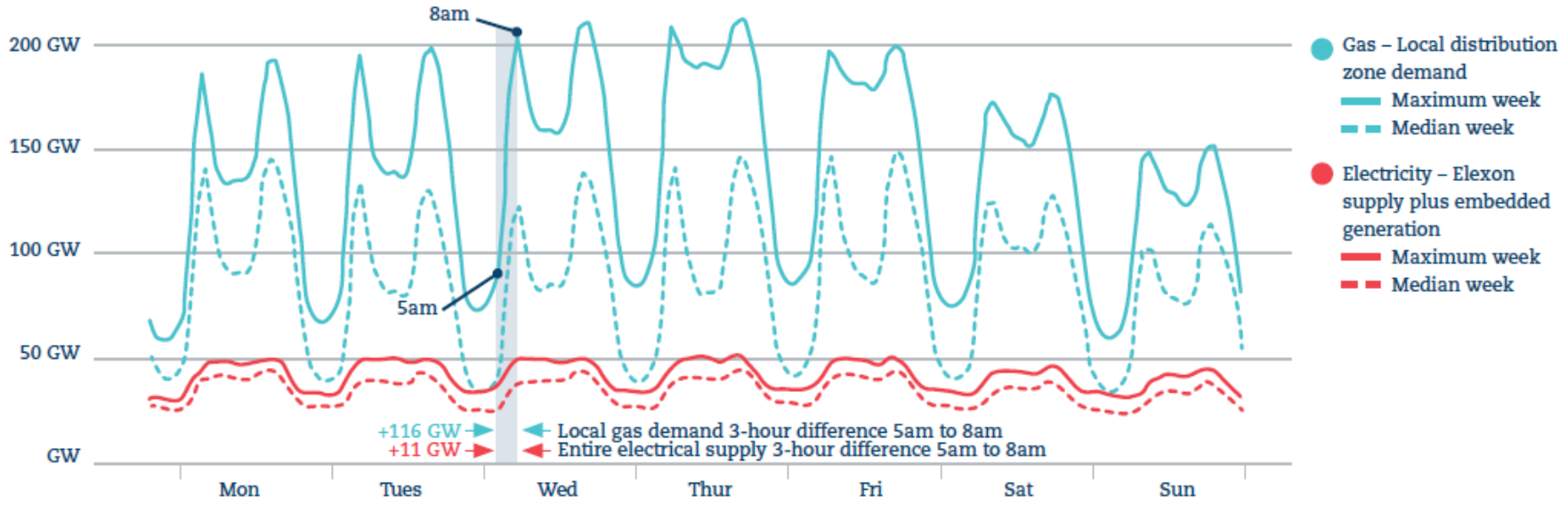
Demand across multiple vectors

On 1st March 2018 at 6pm:

- hourly local gas demand: 214GW
- electrical supply: 53GW



Grant Wilson, University of Birmingham

http://www.ukerc.ac.uk/publications/local-gas-demand-vs-electricity-supply.html

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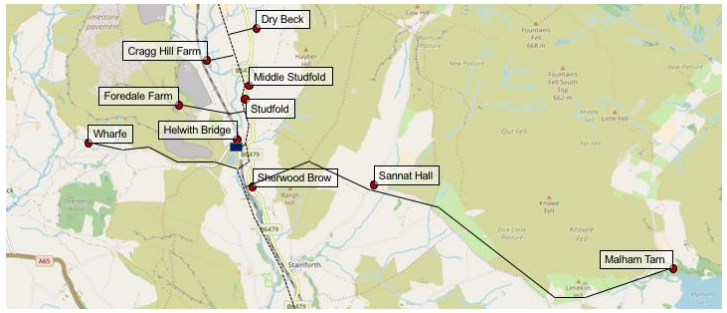
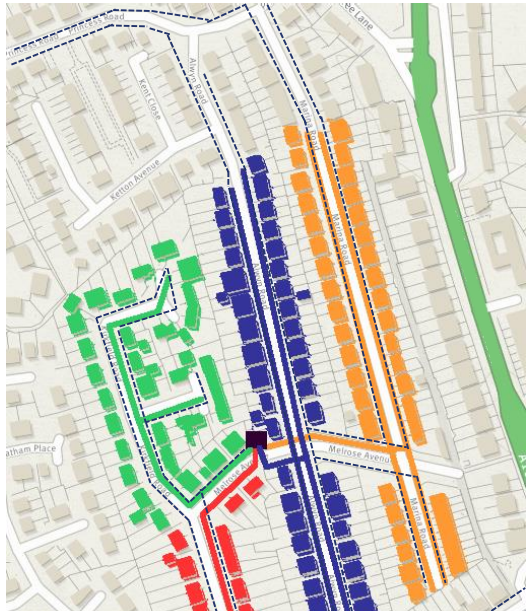
Local Network Modelling

Rural ⟷ **Urban**

Disaggregate UK energy system into exemplar archetypes



Suburban



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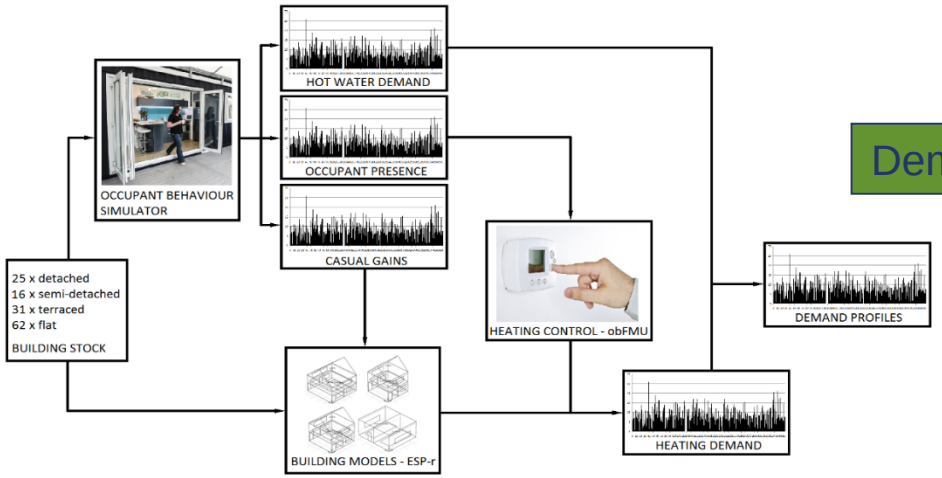
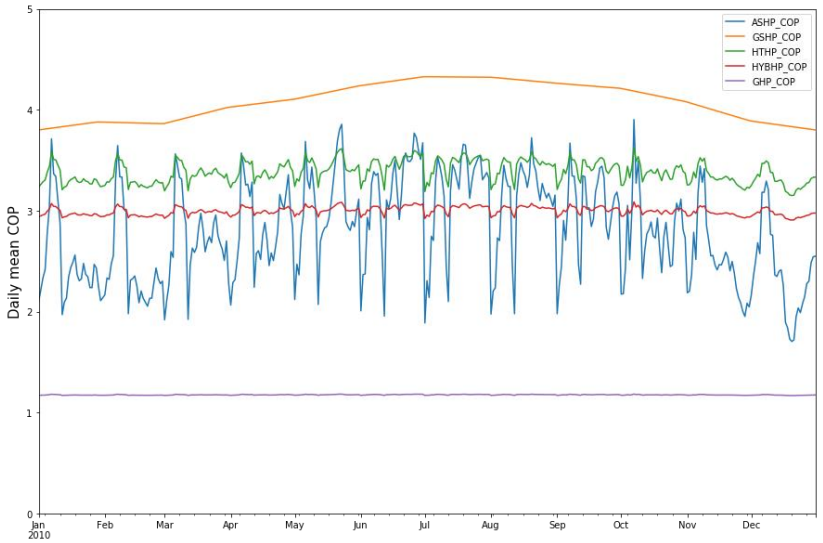
Demand and technology modelling



Demand



Supply

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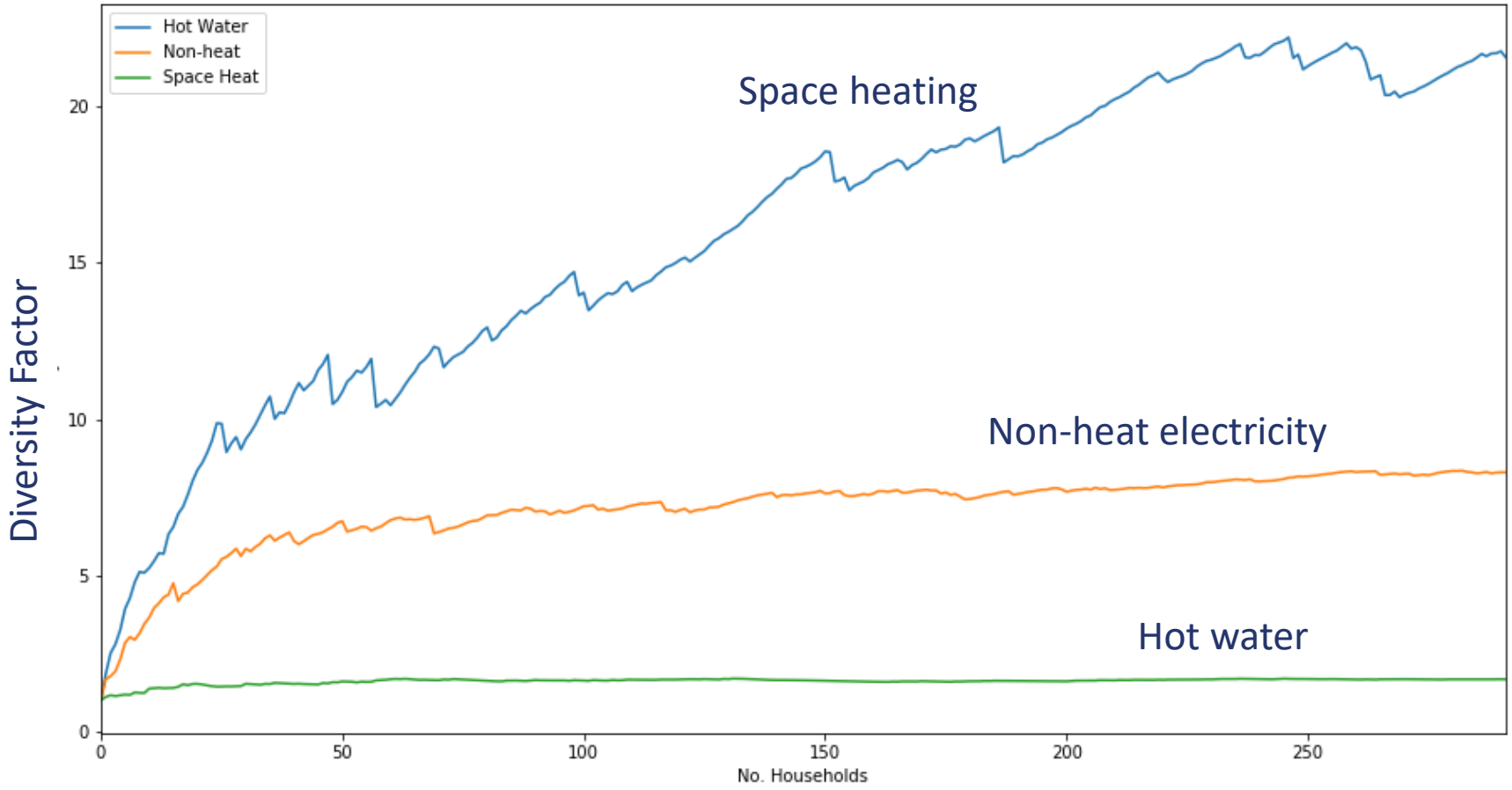
Heat load does not follow existing diversity patterns



Increasing No. Households →

Hawker G. (2018) Spatial and temporal disaggregation of whole system energy models through exemplar local multi-carrier networks

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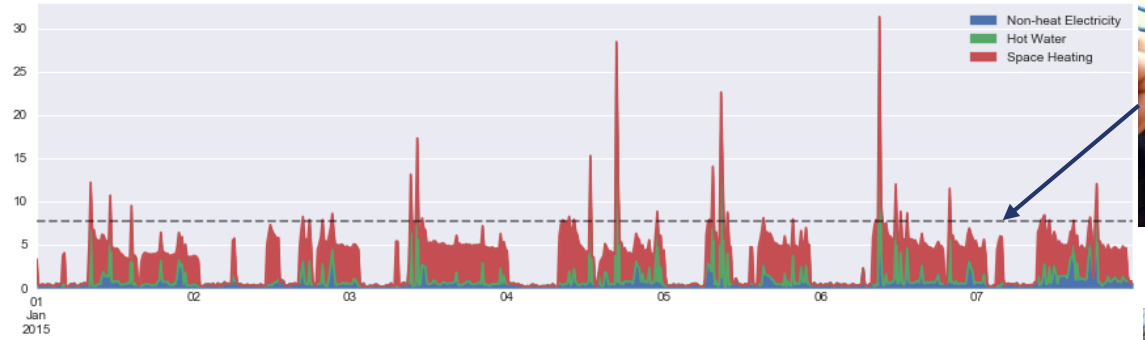
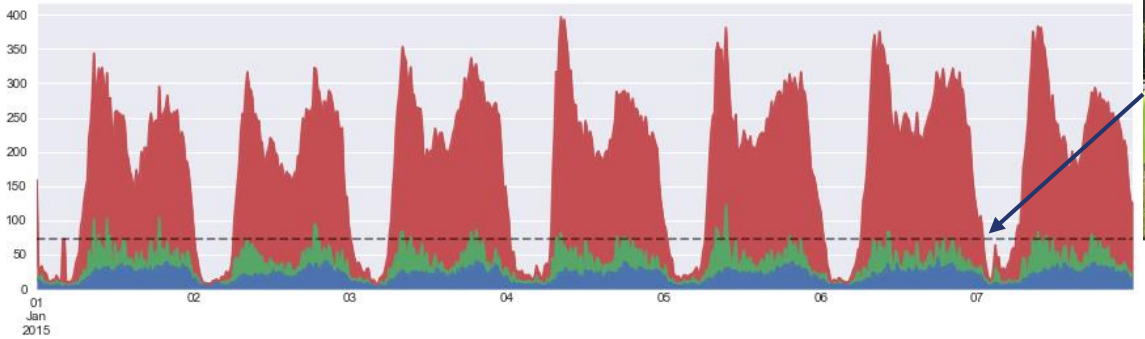
Working with the system we have

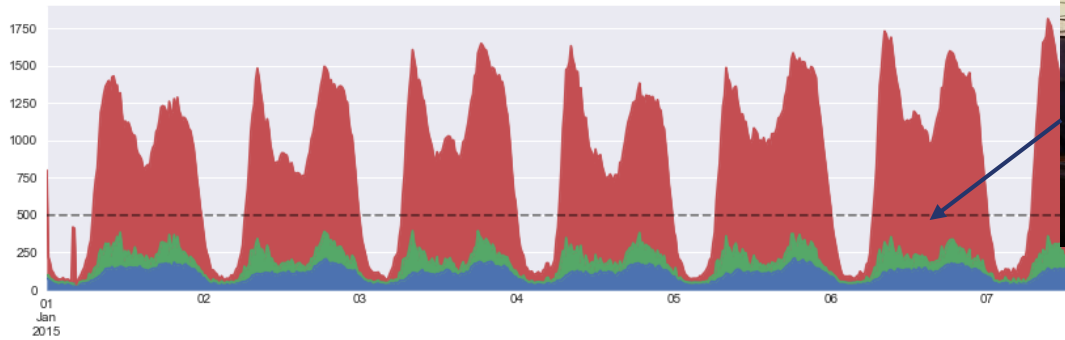
1 house
3 occupants



1 LV Feeder
59 houses
162
occupants



1 LV Xformer
292 houses
697 occupants



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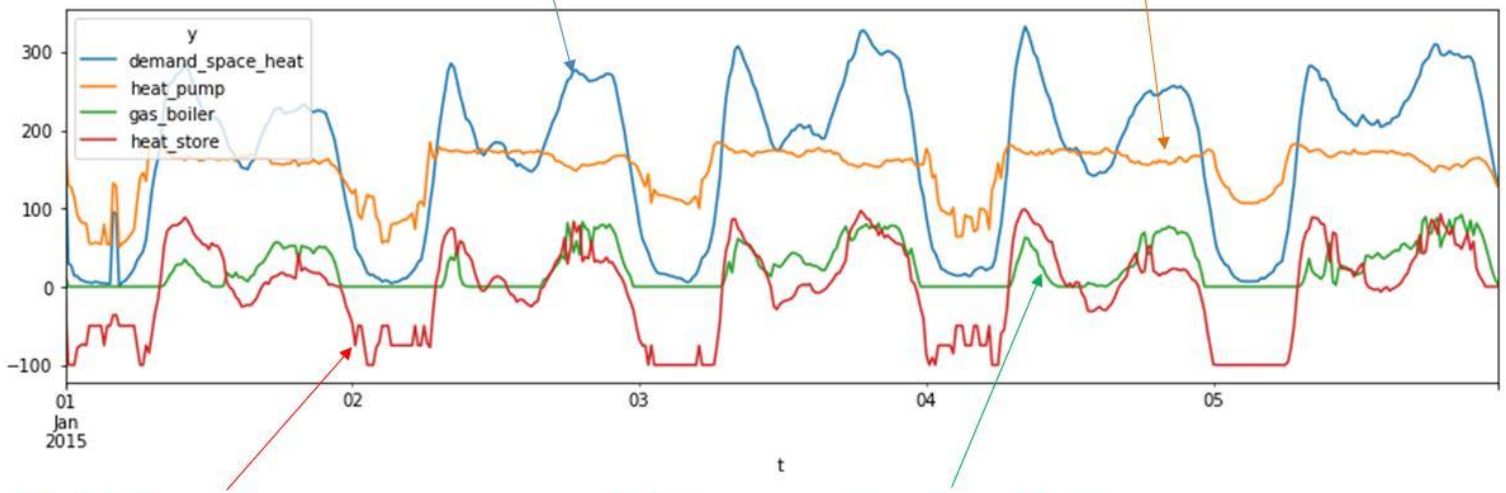
Hybrid solutions and thermal storage

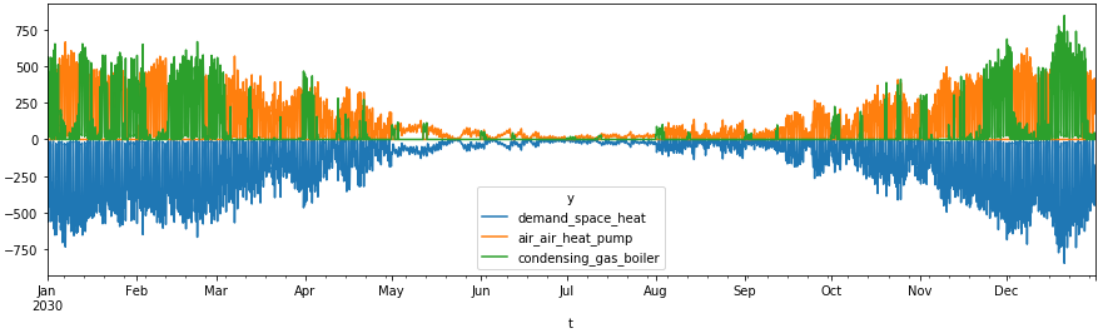
Net space heat demand: building efficiency reduces total energy and provides temporal buffering

Heat pumps utilise decarbonised electricity (local and grid) to limit of network capacity (minus other electrical demand)



Heat storage increases utilization of heat pump capacity

Existing gas network and boilers provide remainder of space heating



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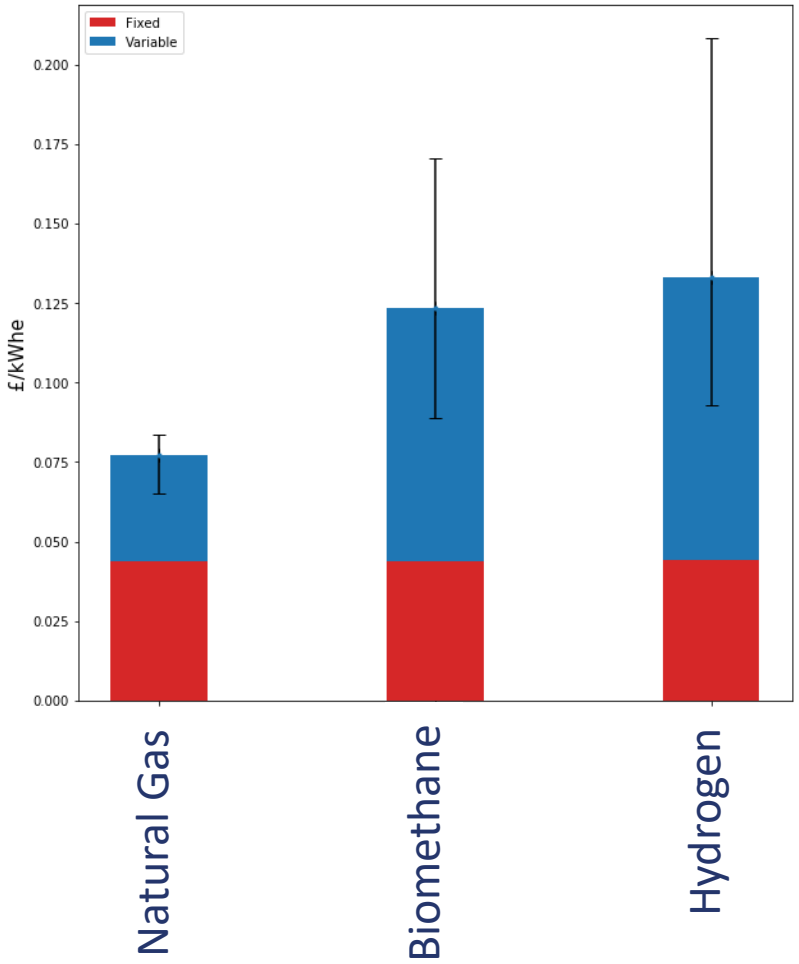
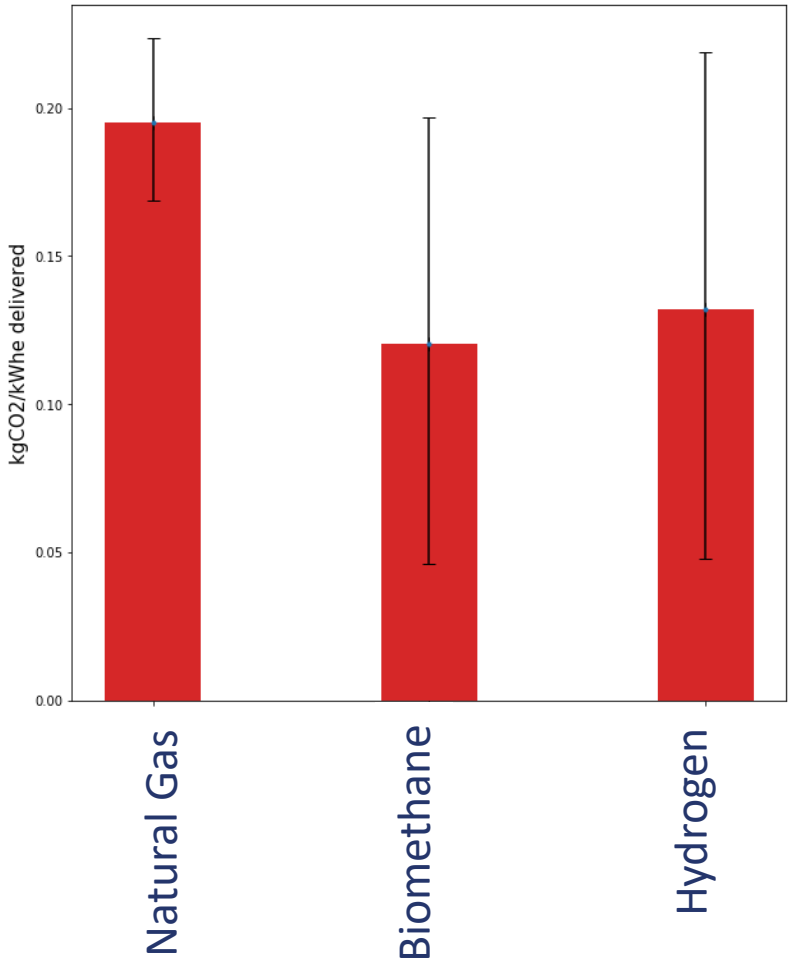
Uncertainties in costs and emissions

Total cost per unit energy delivered (CAPEX + OPEX)



Average carbon emissions per unit energy



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Where has all the hot water storage gone?

- UK domestic new-build properties are shrinking
- Combi boiler installations have ‘freed up’ additional space in many houses which is now being used as living space
- Many new-builds may not have sufficient supportive infrastructure (or space) to retrofit
- BEIS ‘Future Framework For Heat in Buildings’ consultation considered futureproofing for storage in new build requirements

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A false dichotomy?

Electrification

- Demand-side and supply-side changes in parallel
- Huge network implications (in parallel with EV growth)
- Established technologies

vs.

Decarbonising the gas grid

- Little demand-side intervention required
- Wide range of supply-side options (with varying CO2 intensities)
- Sunk cost of networks
- Dependence on new tech

Implies a central coordinator and a need for a single trajectory:

- In reality, we have priority areas (hard to heat homes, off-gas grid, solid fuels)
- Localised supply options (waste heat, biomass)
- A regional approach increases diversity

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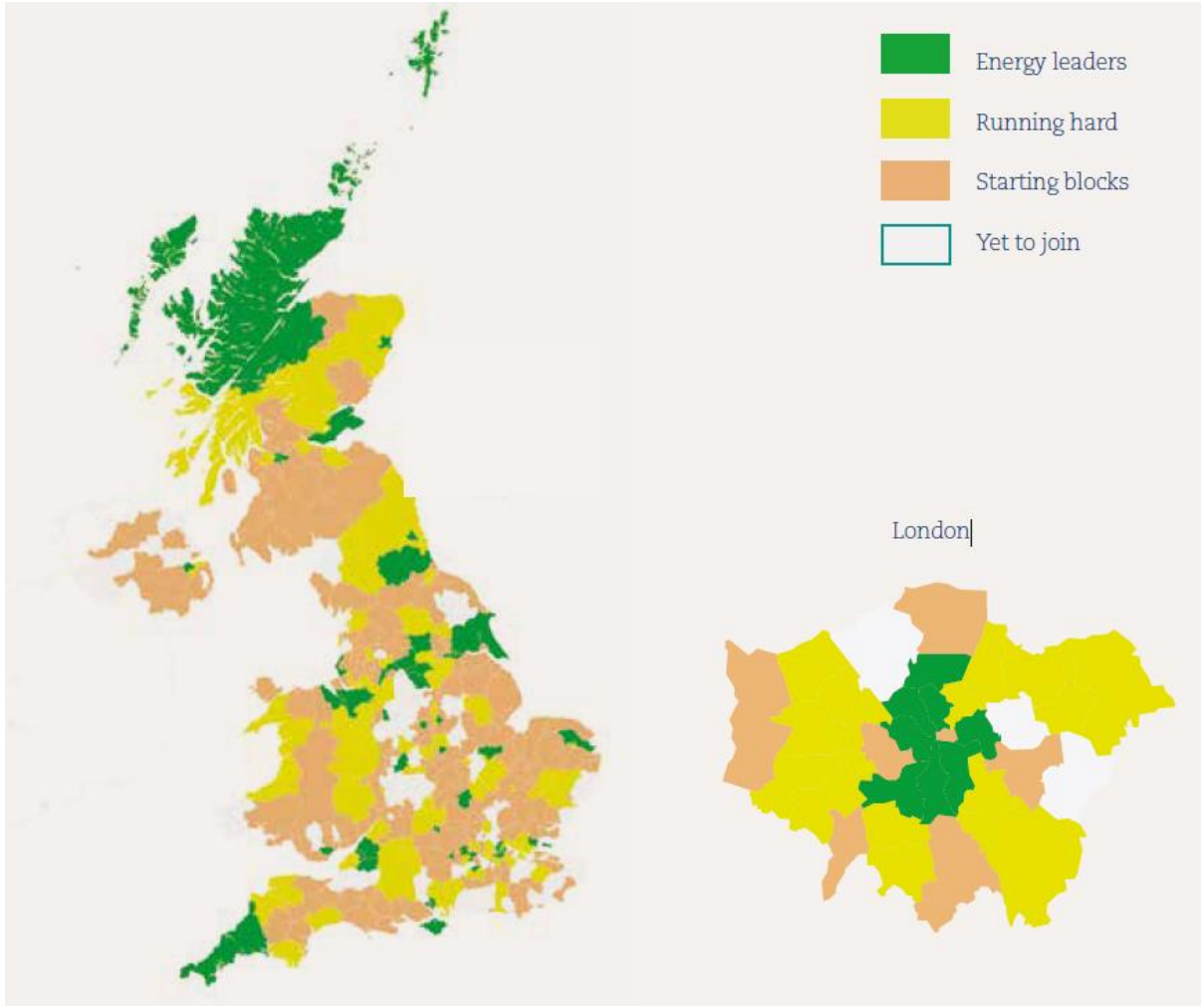
Coordination is complex



Webb, Tingey and Hawkey (2017), What we know about local authority engagement in UK energy systems, UKERC and ETI

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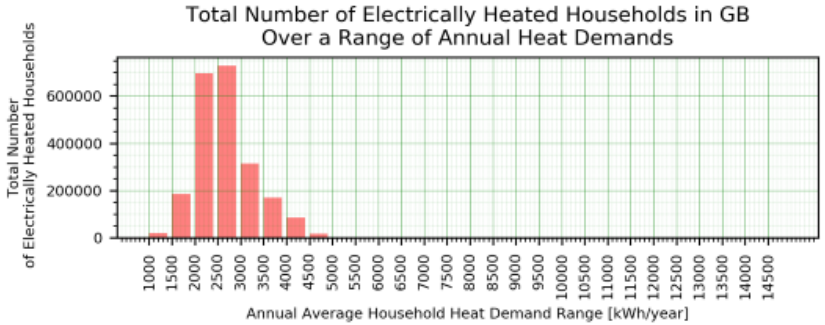
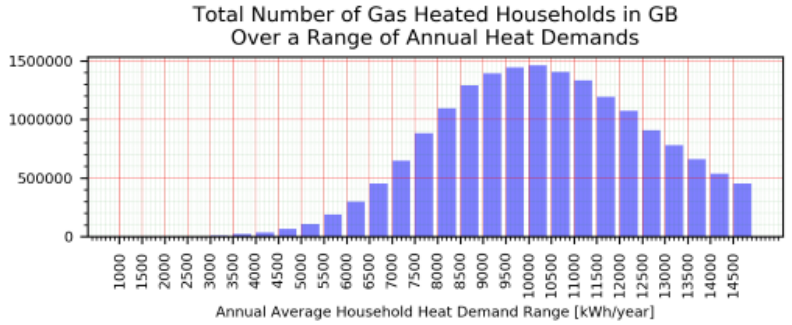
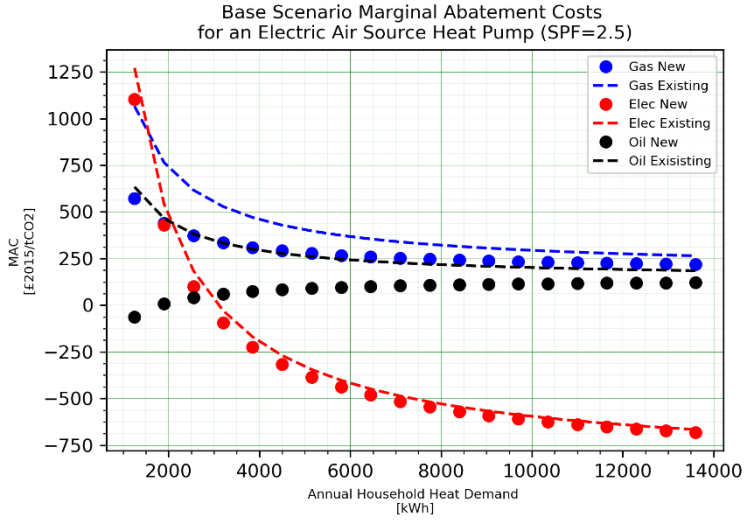
Targeting the right technologies at the right people







Sources: [1] England, Northern Ireland, Scotland and Wales 2011 Census: Office for National Statistics ; National Records of Scotland ; Northern Ireland Statistics and Research Agency (2017): 2011 Census aggregate data. UK Data Service (Edition: February 2017). DOI: http://dx.doi.org/10.5257/census/aggregate-2011-2; [2] UK GOV, Sub-national electricity and gas consumption data 2015

University of Strathclyde IPPI blog October 2018 - **Reducing emissions from heating our homes – does one size fit all?**
https://www.strath.ac.uk/research/internationalpublicpolicyinstitute/ourblog/october2018/reducingemissionsfromheatingourhomesdoesonesizefitall/

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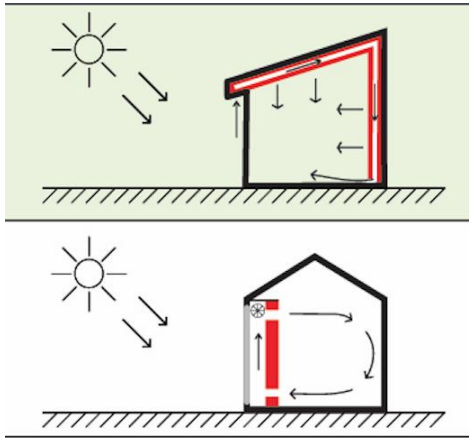
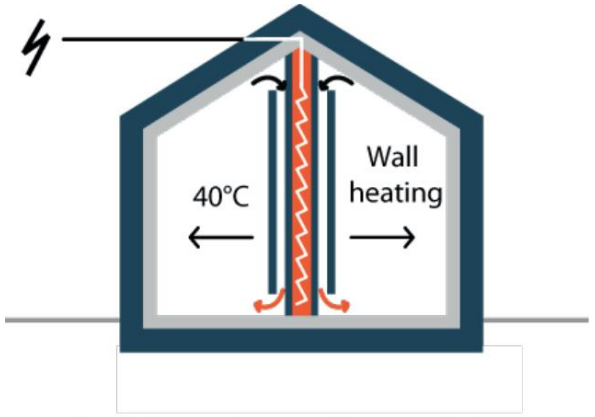
Recognising the link between buildings and networks

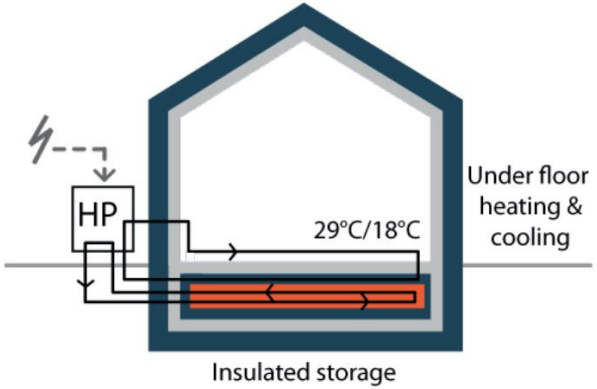


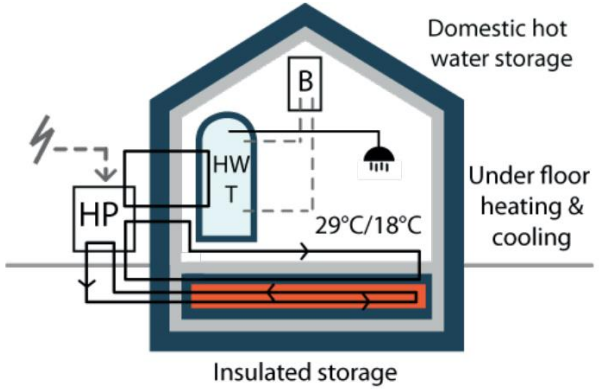


Semi-decoupled ventilated wall storage

Solid Storage heated and cooled with heat pump
Solid storage with water as the heat distribution fluid

Other locations:
Exterior walls and under staircases





Marinho de Castro, M.M. et al., (2018). A Taxonomy of Fabric Integrated Thermal Energy Storage: A review of storage types and building locations. Future Cities and Environment. 4(1), p.5. DOI: http://doi.org/10.5334/fce.6

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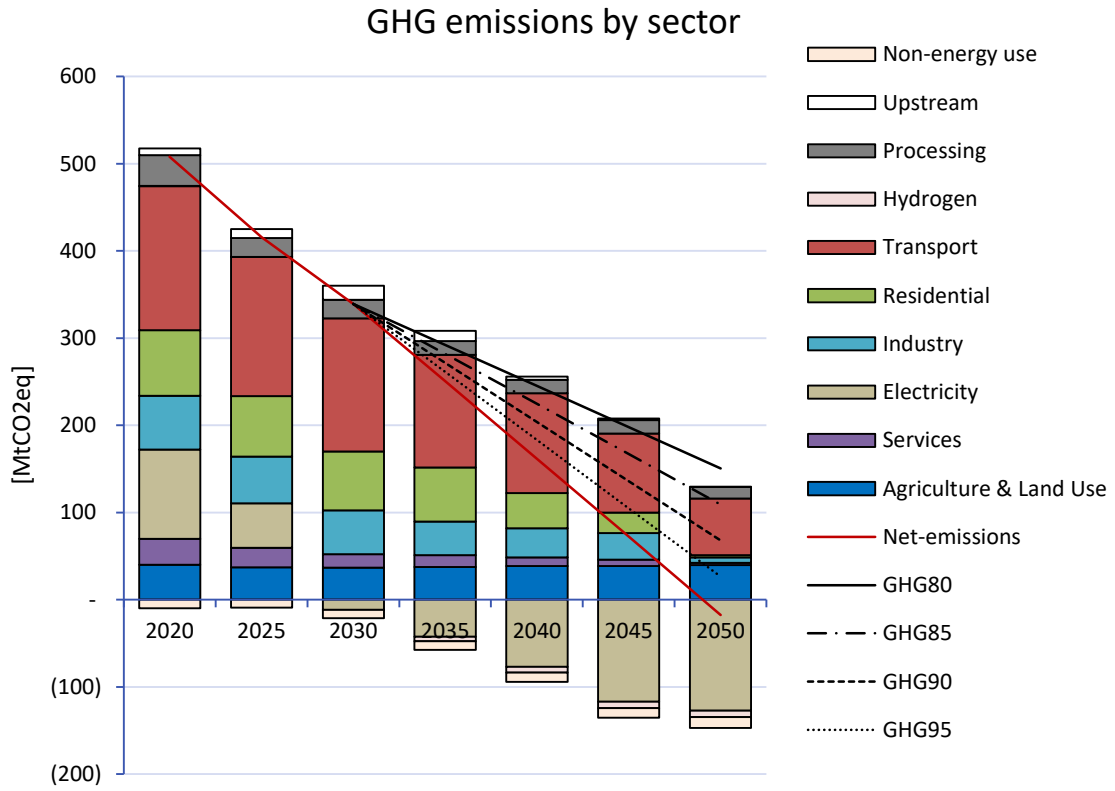
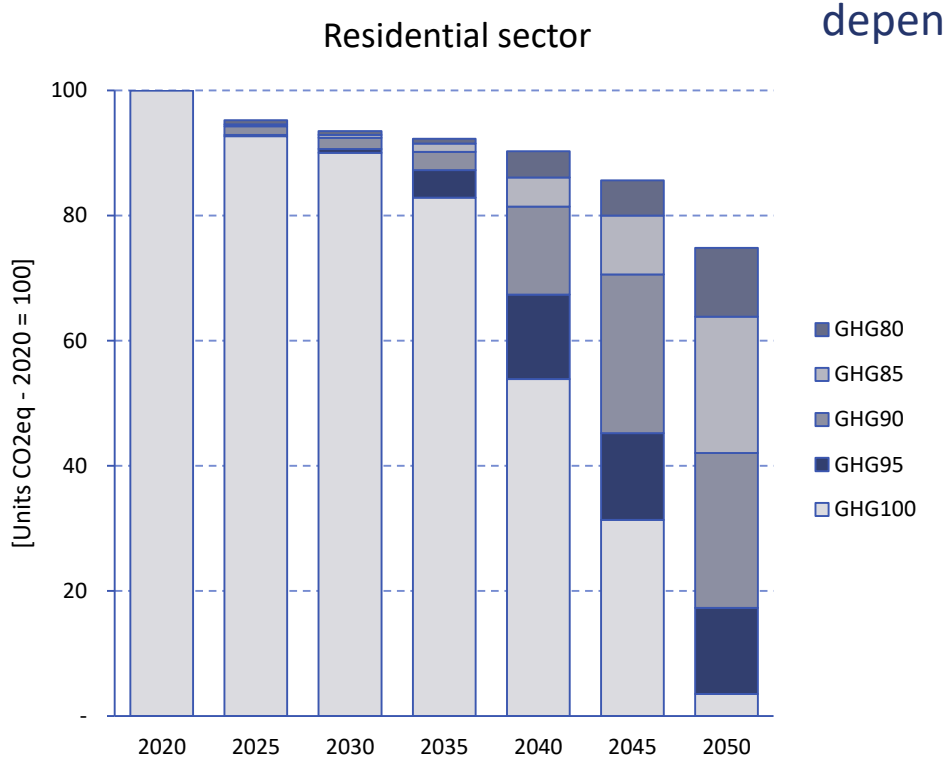
The Whole-System View





Housing sector emissions reduction dependent on 2050 target

Housing sector emissions near-zero under aggressive targets

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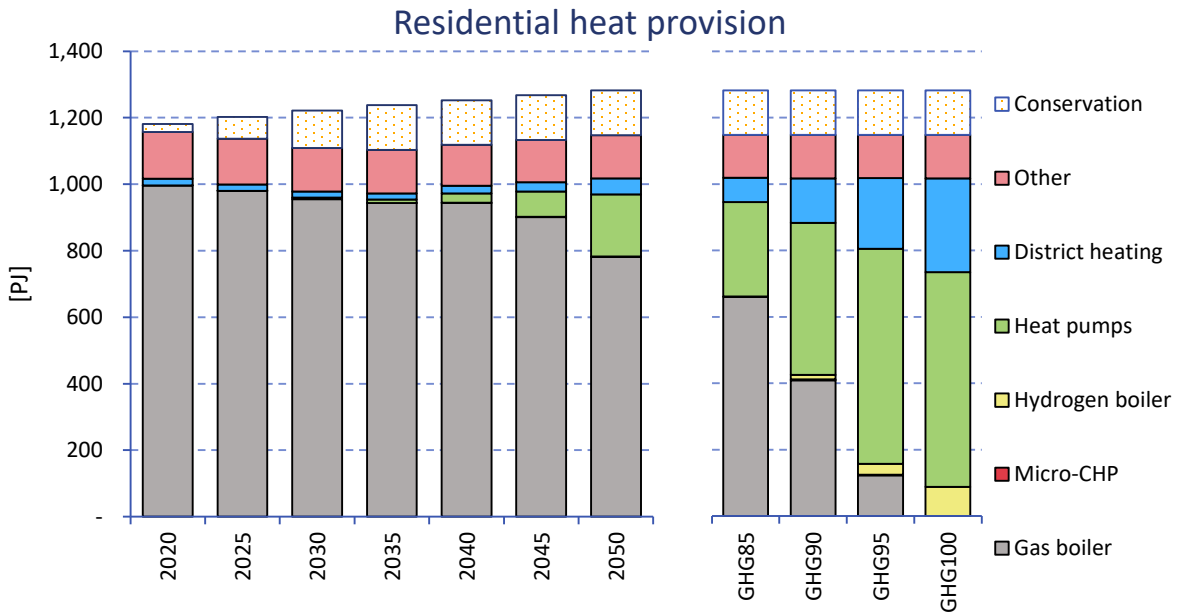
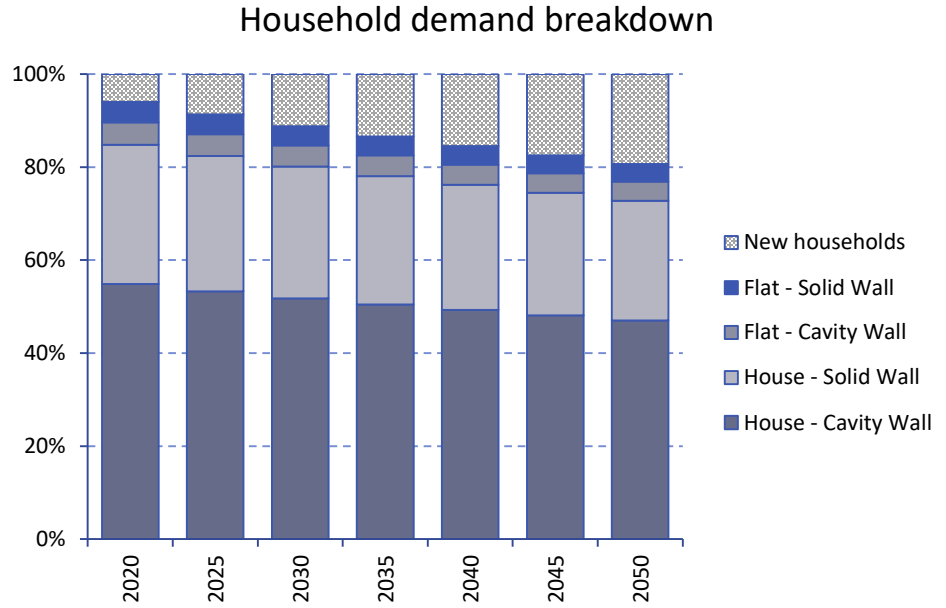
Detail of the Residential Sector





Under 2050 80% reduction scenario, limited use of heat pumps and DH, but under more aggressive reduction scenarios, greater technology diversity is seen

Improved efficiency of new-builds in tandem with efficiency retrofits in existing housing – seen under all reduction scenarios

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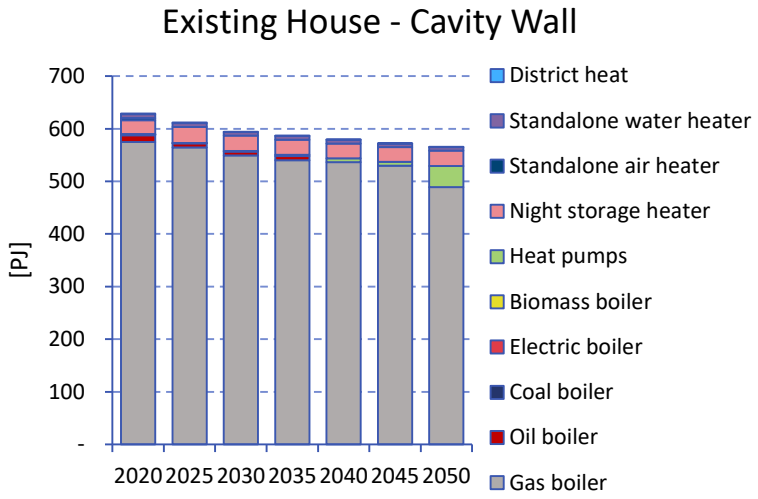
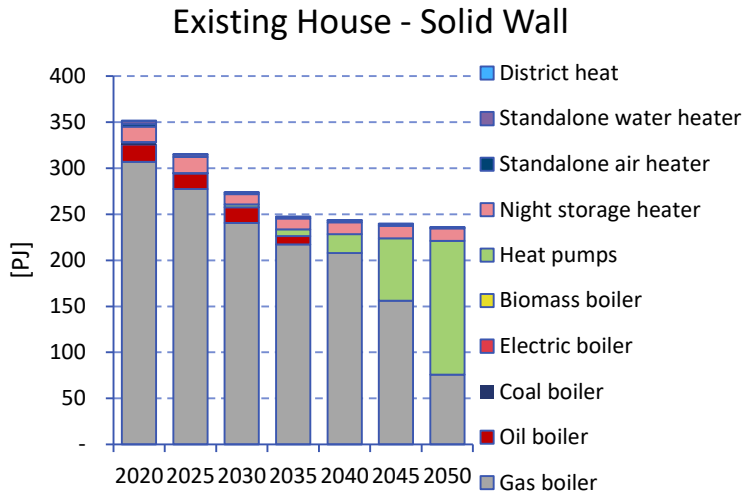
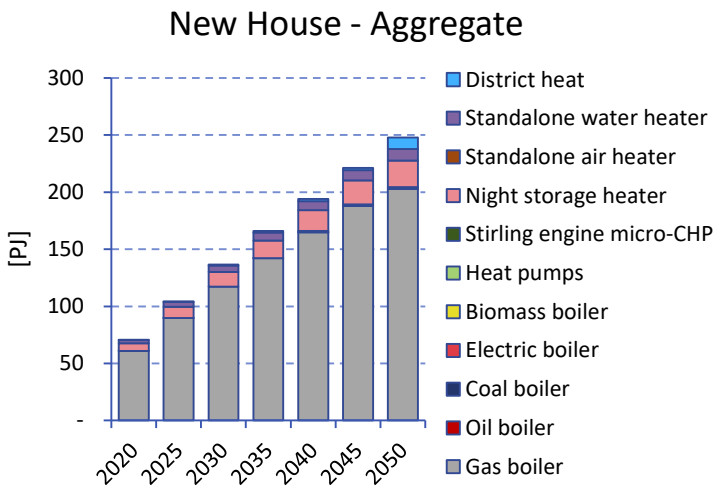
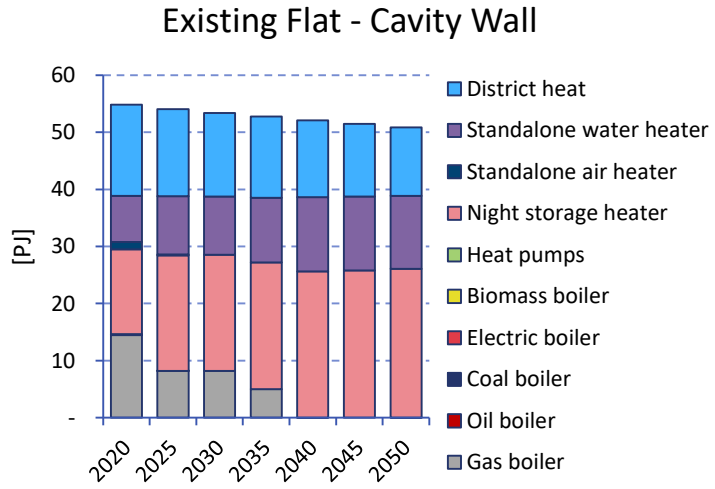
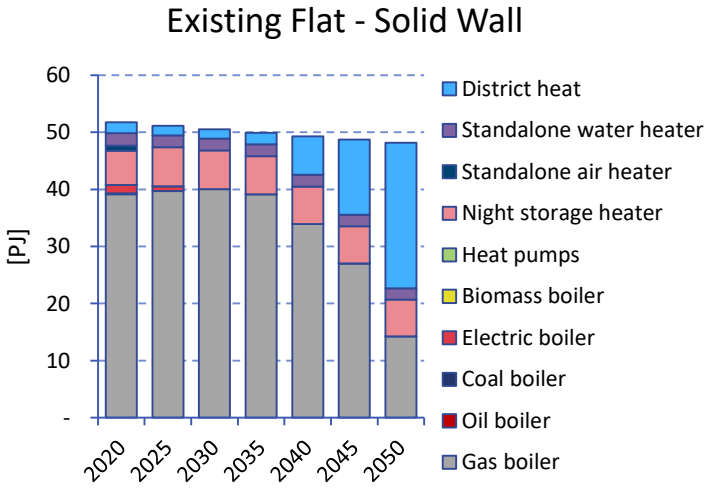
Disaggregation by housing type











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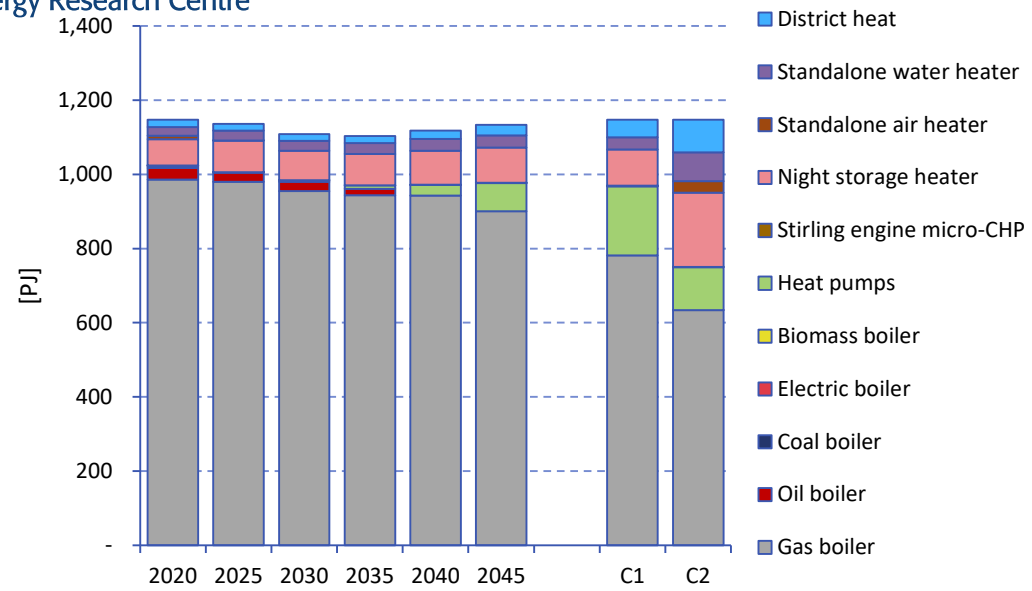
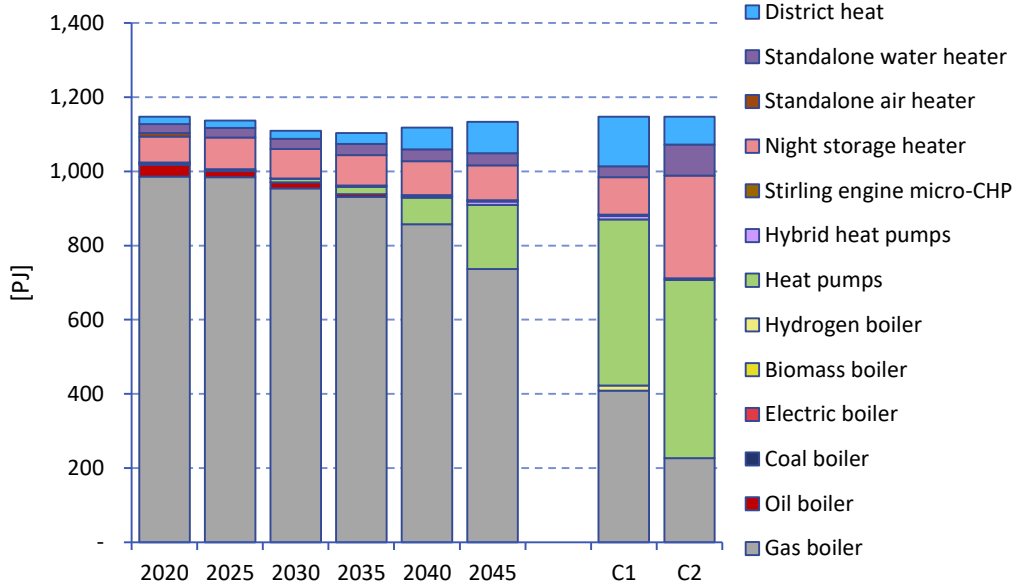
GHG80 alternative case

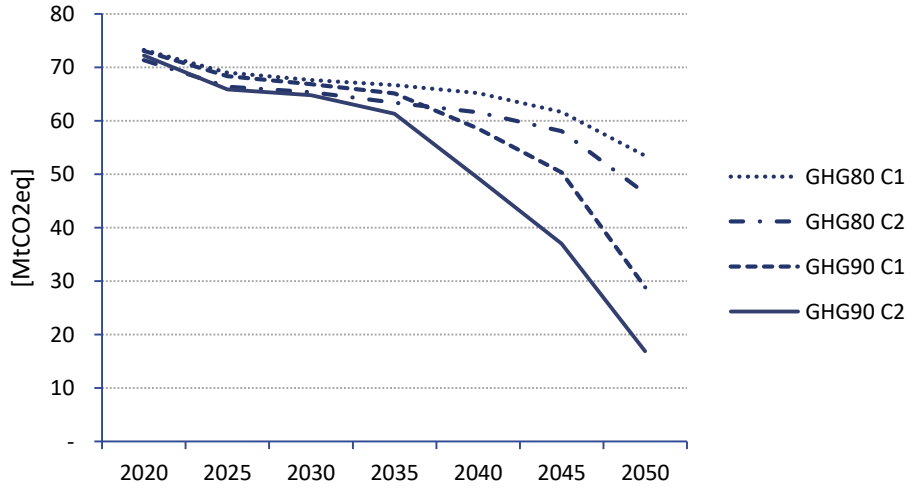


GHG90 alternative cases



Steps taken to accelerate deployment of unconventional systems lead to their increased contribution to emissions reduction over heat pumps – a role for more varied incentives?

Residential sector emissions



…which all combines to increase the role the residential sector may take in the medium term

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Some conclusions

- Building standards and efficiency have direct and significant impacts on network requirements, not only in terms of aggregate demand
- The contribution of residential heat to least cost national decarbonisation may depend on the long-term depth of emissions reduction
- Heat solutions which do not entirely displace incumbent technologies may imply overcapacity of both end-use technologies and network
- The UK is a highly spatially heterogeneous system with a broad variety of extant technologies and use cases, and great care should be taken in extrapolating from case studies
- The least-cost and least-emissions pathways (both for the system and consumer) are subject to high uncertainty
- We are an international outlier in depending on one energy carrier, and there is value in diversifying our current system